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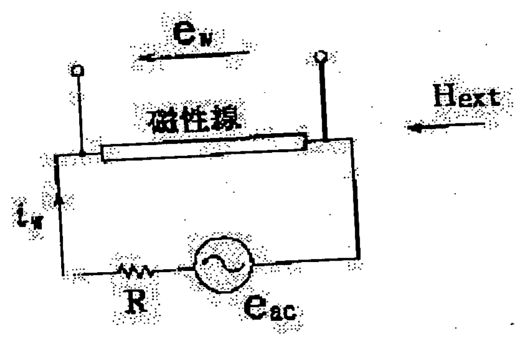
(54) MAGNETIC IMPEDANCE EFFECT ELEMENT

(57)Abstract:
PURPOSE: To obtain the same degree of sensitivity as a flux gage sensor in the same degree of minute size as a magnetic resistance element by making a high-frequency wave of time changing current of a magnetic element changed with an externally applied magnetic field.
CONSTITUTION: Constitution is performed in that an electrical circuit allows alternating current iw to flow in a magnetic line, an external magnetic field (Hext) is applied from the parallel direction of the magnetic line and an amplitude of alternating voltage of both the ends of the magnetic line is measured. An electric resistor R is made a large resistant value of several times or more as large as impedance of the magnetic line and waveform of the current iw allowed to flow in the magnetic line is similarly equal to that of voltage eac of the alternating voltage. The magnetic line such as an amorphous magnetic line having magnetization facility magnetic line is used in a circumference direction.



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CLAIMS

[Claim(s)]
[Claim 1] The magnetic impedance effectiveness component which makes a RF the current which changes force current in time in the magnetic cell to which the electrical potential difference to time amount change of the periphery magnetic flux produced by impressing the current which changes in time to a magnetic line is changed by the external impression field.
[Claim 2] The magnetic impedance effectiveness [that the magnetic line of claim 1 is an amorphous magnetism line] component.
[Claim 3] The magnetic impedance effectiveness component which is the amorphous magnetism line by which the amorphous magnetism line of claim 2 has an easy direction of magnetization in a circumferencial direction.
[Claim 4] It is the magnetic impedance effectiveness component which is the amorphous magnetism line which heat-treated by impressing tension in the die-length direction as an amorphous magnetism line by which the amorphous magnetism line of claims 2 or 3 has compressive force and negative magnetostriction in the die-length direction as an amorphous magnetism line with forward magnetostriction.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the magnetic impedance effectiveness component. This invention relates to the magnetic impedance effectiveness component useful as the magnetic head, various kinds of magnetometric sensors, etc. used for the magnetic scale of a rotary encoder and a numerical-control device which are an audio tape recorder, a video tape recorder, a computer, and a measurement control equipment in more detail.
[0002]
[Description of the Prior Art] Small high performance-ization of an AV equipment, a computer, a measurement control equipment, a numerical-control device, etc. is progressing quickly with development of a microelectronic technology. If it sees especially about a computer related equipment about the floppy disk which it is remarkable, for example, is the external storage for computers, from that whose diameter is 5 inches, a miniaturization is going to progress further and, now, the 2.8 inch time is going to come. Moreover, in the hard disk, it is going to shift to the thing of the diameter of 1 inch.
[0003] However, although it is necessary to miniaturize the magnetic head which is that core in order to miniaturize each of these devices, the miniaturization of this magnetic head has the factor which bars this rather than is necessarily easy. One factor is the problem of the magnitude of the magnetic head itself. That is, the coil of a coil is required for the conventional magnetic head, and the magnetic head itself will be enlarged inevitably. Another is the problem of detection sensitivity. That is, I hear that the relative velocity of the magnetic head and a storage will fall, a detection rate will become small if miniaturized, therefore detection sensitivity will fall remarkably, and it is.
[0004] Then, by the conventional magnetic head, since detection electrical potential differences run short, the motion which uses as a head the magnetic resistance element which detects not time amount change but the magnetic flux itself of magnetic flux has recently come to be seen. Thereby, the miniaturization has been pushed further. However, a current magnetic resistance element has the rate of change of electric resistance very as small as a maximum of 6% or less, and an external magnetic field required to produce several% of magnetic-reluctance change is as large as 20 gauss or more. For this reason, magnetic-reluctance sensibility is the low sensibility below 0.1%/G, and, for this reason, its signal-to-noise ratio (S/N ratio) is also very bad.
[0005] Therefore, although it is necessary to make a magnetic resistance element approach a magnetization object enough, and to use it for it after enabling it to detect only resistance change in a bridge circuit, in fact, in rotary encoders, such as a spindle motor, there is no about dozens of microns gap margin, and it will be [**** / .] in the condition of being easy to produce failure that a motor stops also by invasion of fine dust. Although it is found out when the phenomenon called giant magneto-resistance recently uses a magnetic artificial grid to such a magnetic resistance element, as a matter of fact, a hundreds of gauss big field is required in this case to obtain dozens of% of electric resistance change, there is also a problem of a hysteresis further, and this technique is not suitable for the product which points to a miniaturization.
[0006] Then, the artificer of this invention has already proposed the new component which can conquer the fault of such a conventional magnetic resistance element or the component using the huge resistance effectiveness. That is, generally, if the current which changes to lead wire with magnetism in time [alternating current etc.] is passed, in the both ends of lead wire, the sum of two

kinds of electrical potential differences will appear first. They are an electrical potential difference by the product of the electric resistance of lead wire, and a current, and an electrical potential difference by time amount change of periphery magnetic flux. That is, alternating voltage ew between magnetic line both ends Ohmic electrical-potential-difference eR =R-iw generally according to the electric resistance R of a magnetic line Dielectric electrical-potential-difference eL =dphiB by time amount change dphitheta/dt of magnetic line circumferencial direction magnetic-flux phitheta It can be expressed with sum eW =eR+eL of two components of /dt. Usually, since the latter electrical potential difference was very small, this electrical potential difference was hardly used in engineering to current.

[0007] Then, the new component which the artificer already proposed is a magnetic inductance component which makes it the fundamental principle to detect only the electrical potential difference to time amount change of the periphery magnetic flux produced by impressing the current which changes in time to a magnetic line as change by the external impression field. This magnetic inductance component consists of an electric resistance circuit which takes out only the electrical potential difference to time amount change of the periphery magnetic flux of a magnetic line and its magnetic line. Drawing 1 shows the example of the magnetic inductance component. as a magnetic line in the circuit of this drawing 1 , it is shown in drawing 2 — as — FeCoSiB etc. — from — what bent the becoming zero magnetostriction amorphous thin line, and a straight-line-like thing can also be used.

[0008] It is an inductance part electrical potential difference (eL) by impressing the current (Iw) which changes in time [alternating current etc.] to a magnetic line by the circuit in such a magnetic inductance component, and offsetting the electrical potential difference (ohmic electrical potential difference) by part for electric resistance. It can obtain. It is eL by impressing the general direct-current field and alternating current field which are generated with the means of a permanent magnet or others from the outside to the magnetic line of this magnetic inductance component, for example. Amplitude |eL | can decrease and an external impression field can be detected.

[0009] this magnetic inductance component — setting — as for example, a magnetic line — FeCoSiB from — becoming as-cast External magnetic field H1 impressed on a magnetic line in parallel using the zero magnetostriction a-wire the die length of a wire is changed — making — each inductance part electrical potential difference eL When amplitude |eL | is measured, it comes to be shown in drawing 3 .

[0010] As for (a), in 30mm and (b), in this drawing 3 , the die length of a wire measures [as for 10mm and (c)] ** |eL | about the magnetic inductance component whose die length of a wire the die length of a wire is 2mm for the die length of a wire, as for 5mm and (d).

[0011] For example, as shown in drawing 3 (a), with a-wire of 30mm length, it is H1. About 1 (Oe) |eL | which can be set is H1. 0 (Oe) To |eL0| which can be set, it is decreasing about 50% and high sensitivity comparable as the conventional flux gate form field sensor is shown. At this time, if H2 of a perpendicular direction is impressed to the die-length direction of a wire, |eL | will hardly change. That is, the magnetic inductance component has strong directivity, and a S/N ratio becomes remarkably high when applying to a bearing sensor etc., since only a detecting-signal-ed field is detected alternatively. Moreover, with the amorphous wire which gave tension annealing, the electrical-potential-difference change property of high sensitivity [like drawing 3 (a)] even whose die length of 1-2mm is was also found out.

[0012] However, it has turned out that the point which should be improved exists also in this new component by examination of the artificer of this subsequent invention. A compensating network called a bridge circuit is required for this magnetic inductance component smell like the case where a magnetic resistance element is used, therefore that is because there was a limitation in a miniaturization naturally. Moreover, adjustment of a compensating network took time and effort, and the difficulty was in operability.

[0013] This invention is made in view of the situation as above, conquers the fault of the conventional magnetic resistance element, and aims at offering the new micro magnetic cell which has high sensitivity comparable as a flux gate sensor with a minute dimension comparable as a magnetic resistance element.

[0014]

[Means for Solving the Problem] This invention offers the magnetic impedance effectiveness

component which makes a RF[illegible] current which changes in time in the magnetic cell to which the electrical potential difference to time amount change of the periphery magnetic flux produced by impressing the current which changes in time to a magnetic line as above-mentioned The means for solving a technical problem is changed by the external impression field.

[0015]

[Function] That is, this invention smell has the big description in having made the bridge circuit unnecessary by high-frequency-izing the energization current in the conventional magnetic inductance component. For example, drawing 4 is the simplest electrical circuit for realizing this invention, and is alternating current iw to a magnetic line. It energizes, an external magnetic field (Hext) is impressed from the parallel direction of a magnetic line, and the configuration which measures amplitude |ew | of the alternating voltage between the both ends of a magnetic line is made.

[0016] Alternating current iw which gave the big resistance of several times or more of the impedance of a magnetic line to electric resistance R, and was energized on the magnetic line, for example in drawing 4 in this invention It is desirable to make it a wave become almost equal to the wave of the electrical potential difference eac of the source of alternating voltage. In this invention, the magnetic impedance effectiveness component characterized by using an amorphous magnetism line as a magnetic line may be used, and the amorphous magnetism line which has an easy direction of magnetization in a circumferencial direction may be further used as that amorphous magnetism line. Furthermore, the amorphous magnetism line which heat-treated by impressing tension in the die-length direction may be used for the amorphous magnetism line which has compressive force and negative magnetostriction in the die-length direction as the amorphous magnetism line at an amorphous magnetism line with forward magnetostriction.

[0017] An example is shown below and this invention is explained in more detail.

[0018]

[Example]

an example 1 — actually — the magnetic impedance effectiveness component of this invention — an amorphous magnetism line — high frequency current iw Ohmic electrical potential difference er at the time of carrying out energization excitation and impressing an external magnetic field ****** eL Sum ew The value of amplitude |ew | was measured.

[0019] For example, for drawing 5 , a diameter is iw 100kHz or more about 30 micrometers and an amorphous magnetism line with a die length of 5.5mm. Ohmic electrical potential difference er at the time of carrying out energization excitation and impressing the external magnetic field of Hext =0(Oe), Hext =10(Oe), and (800 A/m) ****** eL Sum ew It is the result of showing the value of amplitude |ew |. In Hext =0(Oe), in this drawing 5 , the dotted line of a continuous line is the case of Hext =10 (Oe) and (800 A/m). This amorphous magnetism line impresses 2kg /of tension of 2 mm, and is 475 degrees C and 1min. Annealing is given for annealing.

[0020] As illustrated to this drawing 5 , it is Hext of |ew |. The change by impression appears in f> 200kHz, and by f= 1-2MHz, when the external magnetic field of Hext =10(Oe) is impressed, |ew | shows about 50% of reduction. Such a phenomenon is a phenomenon in which it did not see in the old magnetic substance, and especially the MR effectiveness's having shown up by the small (1% or less) amorphous magnetism line is not expected at all until now. Drawing 6 is iW in f= 1MHz of drawing 5 , and iw =15mA, and ew (Hext =0). And ew (Hext =10(Oe)) It is a wave-like photograph. It is [as opposed to / as illustrated to this drawing 6 / sinusoidal current] eW (Hext =0). A wave is a horned wave and is ew (Hext =10(Oe)). A wave is iw. It is almost the same as a wave. Since it is not the wave which was remarkably different from the sine wave widely, this wave of ew (Hert =0) is ew. iw If a magnetic line impedance is set to Z when a sine wave is considered, it is Hext of |ew |. It can be considered that receiving change is change of |Z|. Therefore, it decided to call the magnetic cell of this invention the magnetic impedance effectiveness component (Magneto-Impencance component; MI component).

an example 2 — the magnetic impedance effectiveness component of this invention — an amorphous magnetism line — high frequency current iw Energization excitation was carried out and the magnetic impedance characteristic which is the relation between change of an external impression field and |ew | was investigated.

[0021] Drawing 7 is the magnetic impedance characteristic of the amorphous magnetism line used in

the example 1, and is the result of measuring the case of iw =7.5mA and [illegible]A in f= 1MHz. As illustrated to this drawing 7 , even if it uses the simplest circuit of only detecting the electrical potential difference between both ends for the magnetic line which energized the alternating current which |ew | was decreasing about 50% by Hext =5(Oe), for example, was illustrated to drawing 2 , the thing which are equal to the conventional flux gate sensor and which is acquired for the magnetic-flux sensing element of high sensitivity very much is possible.

an example 3 — delta|ew at the time of changing the path of an amorphous magnetic line The frequency characteristics of |/|ew | were investigated.

[0022] Drawing 8 is delta|ew at the time of changing the amorphous magnetic line used in the example 1. They are the frequency characteristics of |/|ew |. As illustrated to this drawing 8 , by the magnetic line of the diameter of 124 micrometer, and the magnetic line of the diameter of 50 micrometer, rate of change showed max by f= 200kHz and about 600kHz, respectively. Especially the rate of change at the time of using the magnetic line of the diameter of 50 micrometer is the largest in these three, and that value showed about 60%.

[0023] The origin of this magnetic impedance effectiveness is the internal inductance Li of a magnetic line, if it considers from two curves shown in drawing 5 . It is the electric resistance Rw of a magnetic line to change and coincidence. It thinks for changing with the skin effects. That is, it is [0024], when the skin effect is strong (the continuous line of drawing 5 f> 200 KHZ), an impedance Z makes delta the skin depth and it makes a a magnetic line diameter.

[Equation 1]

$$Z = Rw\frac{a}{2\delta} + jLi\frac{2\delta}{a}$$

[0025] A next door, [0026]

[Equation 2]

$$|Z| \propto \sqrt{\mu_0}$$

[0027] (mu0 : Since it becomes periphery permeability), it is mu 0 at Hex. It decreases and |Z| decreases sharply.

an example 4 — the magnetic impedance component of this invention was used for the field sensor. Drawing 9 is the example of the resonance mold multivibrator by MI component and FET combination. In this resonance mold multivibrator, using the detailed amorphous magnetism line of 1mm length of diameters of 30 micrometer, the 220MHz self-oscillation could be produced and the field detection property with good linearity was able to be acquired in the external impression field to **2 (Oe). Resonance is produced in the inductance of a magnetic line, and the internal capacitance between the source drains of FET. In this resonance mold multivibrator, power consumption was 8mW very small.

[0028] The property of MI component used as the fundamental structure of the resonance mold multivibrator by this MI component and FET combination becomes as it was shown in drawing 10 . This MI component is the reverse bias direct-current field Hb mutually for two MI components. It impresses and is each eW. A difference is in direct proportion to the external impression field Hex. Drawing 11 is Hb in MI component of the self-oscillation circuit of drawing 7 . It is as a result of [at the time of not impressing but establishing only one tip of MI component in the location of 0.5mm of ring magnet front faces of the diameter of 30mm 512 pole magnetization for rotary encoders of a floppy disk drive spindle motor] magnetic pole field detection. In this case, magnetic pole spacing was 150 micrometers. The clear magnetic pole field was detected by the twice [number-of-cases] as many gap margin using a magnetic resistance element as this.

[0029]

[Effect of the Invention] The very highly sensitive small magnetic impedance effectiveness component which it becomes unnecessary to use a bridge circuit and obtains 50% or more of impedance change by the several gauss field by making an energization current high-frequency-ize by this invention is offered as explained in detail above. By furthermore using this impedance effectiveness component, the magnetic head with it is offered. [it is highly sensitive and very, small]

[0030] When the magnetic impedance effectiveness component of this invention is used for example, for a field sensor, it becomes it is possible to raise the sensibility of the conventional hall device

about 100 times, and still mo[illegible]ssible [the service temperature of a h[illegible]] to increase to about 200 degrees C to the case of the conventional hall device being destroyed at about 70 degrees C. Furthermore, if the magnetic impedance effectiveness component of this invention is used for a rotary encoder head, high sensitivity of about 100 times or more can be realized to the conventional MR component, the gap on a head and the front face of a magnet can be detached to about 0.5mm, and things will become possible about the failure accident by invasion of a contaminant etc. If the magnetic impedance effectiveness component of this invention is used, various kinds of high sensitivity micro magnetometric sensors, such as a very small micro magnetometric sensor for an earth magnetism use electronic bearing component or micro machines, a magnetic flaw detection sensor array of high sensitivity, and a magnetism-of-living-body sensor, will become possible.

[Translation done.]

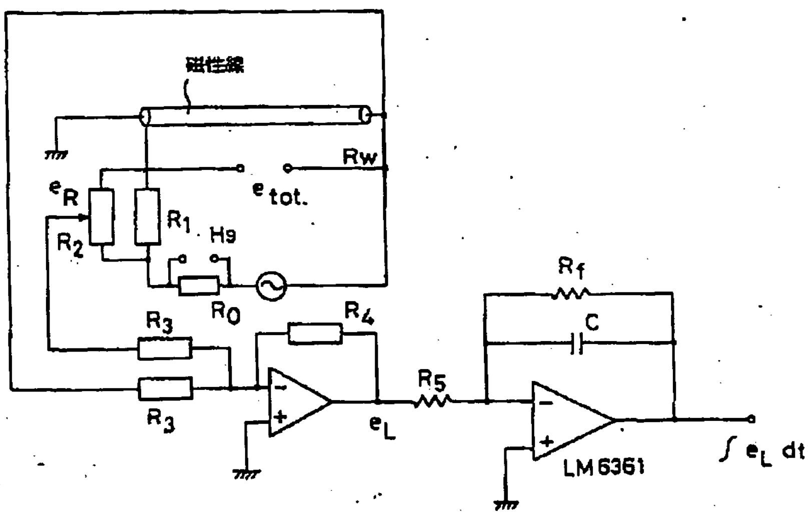
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the schematic diagram having shown the conventional magnetic inductance component.
[Drawing 2] It is the top view having shown the magnetic line of the conventional magnetic inductance component.
[Drawing 3] (a), (b), (c), and (d) are the wave form charts having shown respectively the wave of the magnetic inductance which used the conventional magnetic inductance component.
[Drawing 4] It is the schematic diagram having shown the magnetic impedance component of this invention.
[Drawing 5] It is the correlation diagram having shown the relation between the electrical potential difference between magnetic line both ends, and the frequency of the high frequency current.
[Drawing 6] It is the wave form chart showing the output wave in this invention.
[Drawing 7] It is the correlation diagram having shown the relation between the electrical potential difference between magnetic line both ends, and an external impression field.
[Drawing 8] It is the correlation diagram having shown the relation between the rate of the change of potential between magnetic line both ends, and a high-frequency-current frequency.
[Drawing 9] It is a schematic diagram at the time of using the magnetic impedance component of this invention for a field sensor.
[Drawing 10] It is the correlation diagram having shown the relation between the electrical potential difference between the magnetic line both ends at the time of using the magnetic impedance component of this invention for a field sensor, and an external impression field.
[Drawing 11] It is the wave form chart having shown the magnetic pole field detection result.

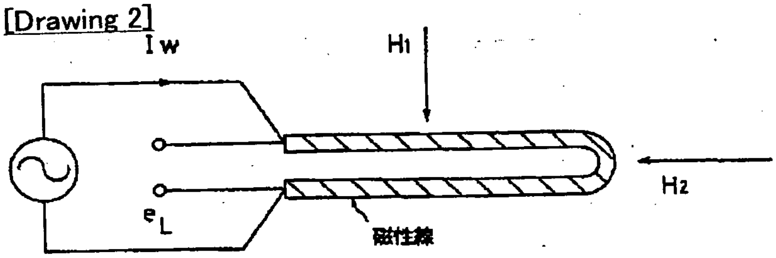
[Translation done.]

DRAWINGS

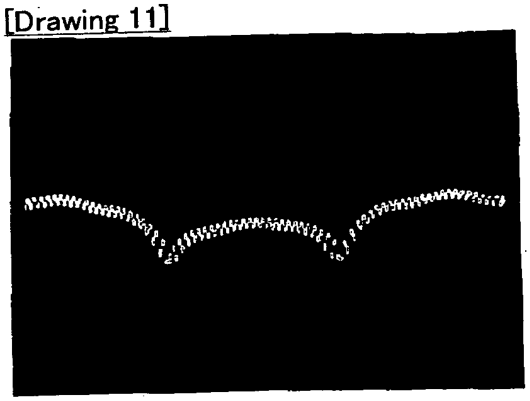
[Drawing 1]



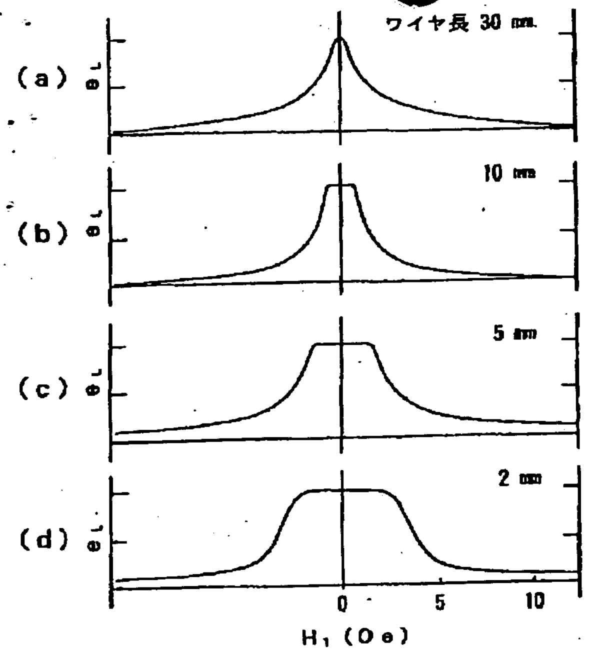
[Drawing 2]



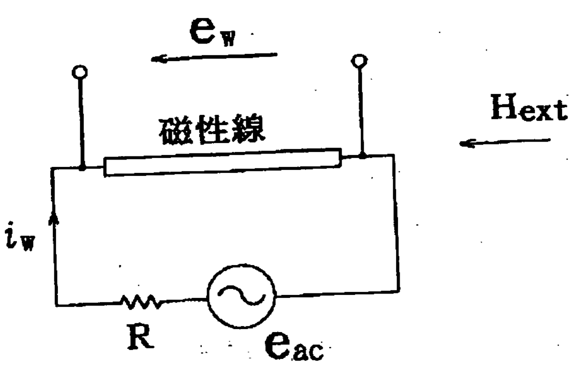
[Drawing 11]



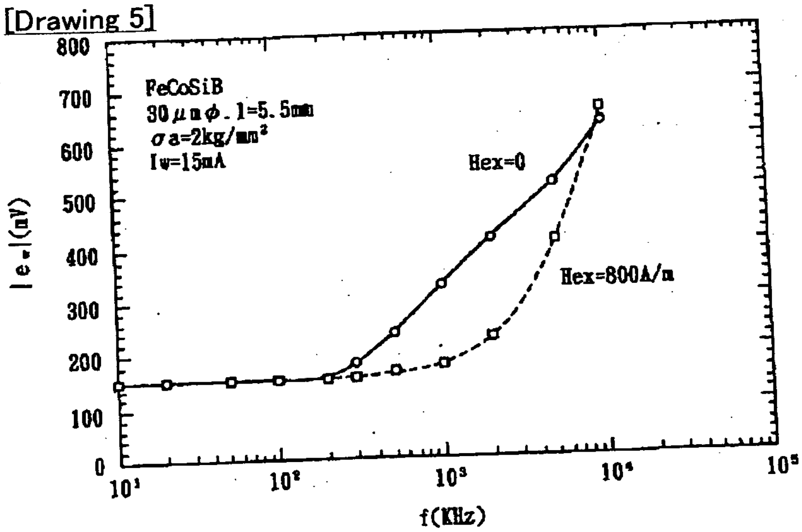
[Drawing 3]



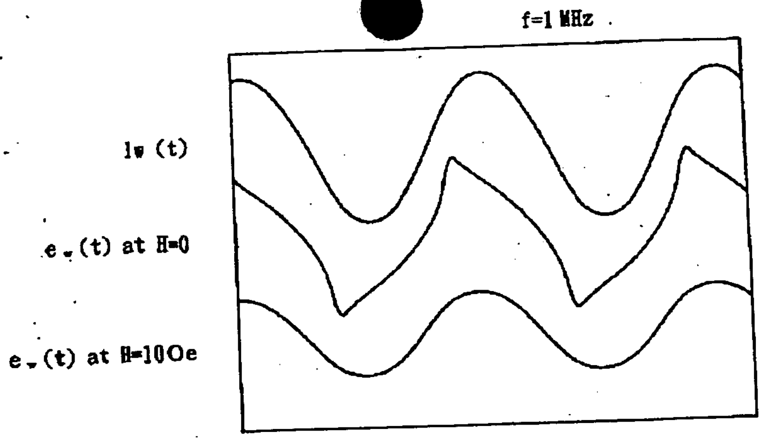
[Drawing 4]



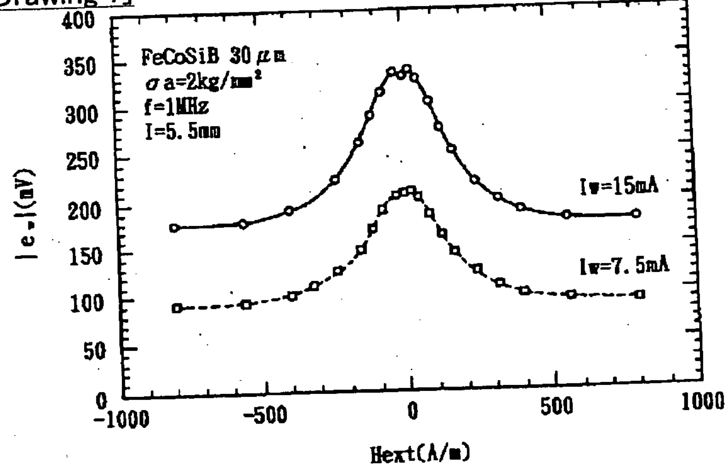
[Drawing 5]



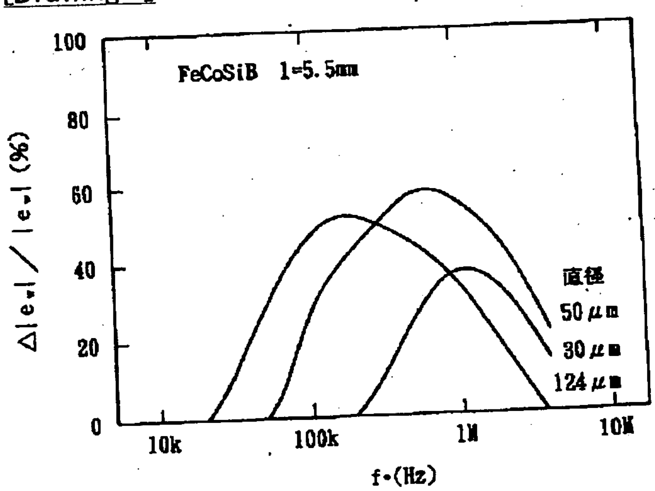
[Drawing 6]



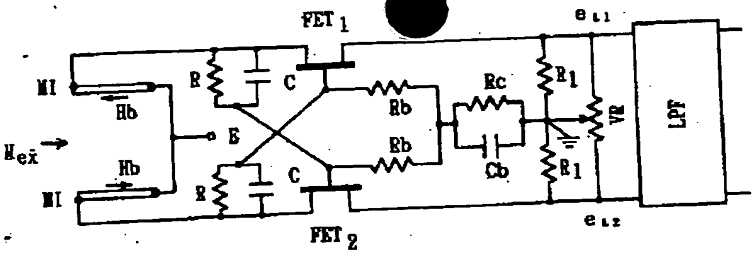
[Drawing 7]



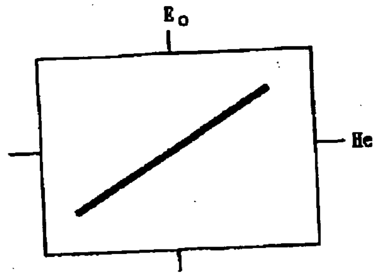
[Drawing 8]



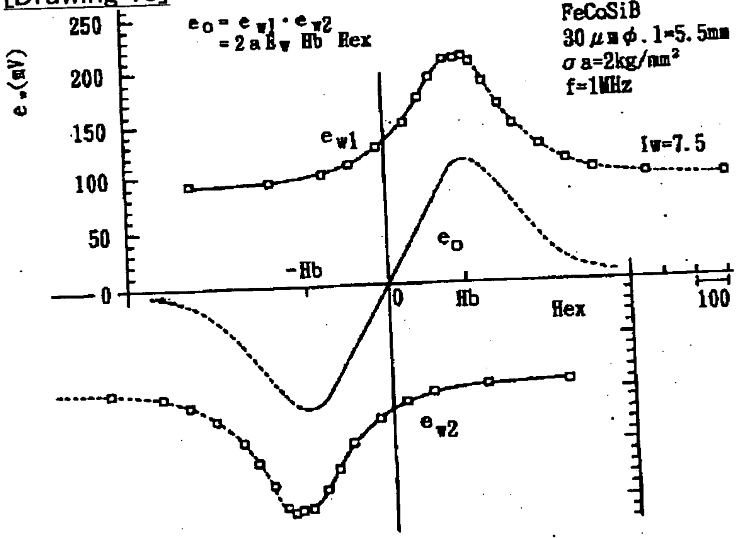
[Drawing 9]



FeCoSiB 30μm 直径
1 mm 長さ
f_{osc} = 220 MHz
バイアス dc (300A/m)
;一対のコイルによる



[Drawing 10]



[Translation done.]

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G01R 33/04		8203－2G		
G11B 5/127		7303－5D		
			H01F 1/14	C

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(21)出願番号　特願平5－323816

(22)出願日　平成5年(1993)12月22日

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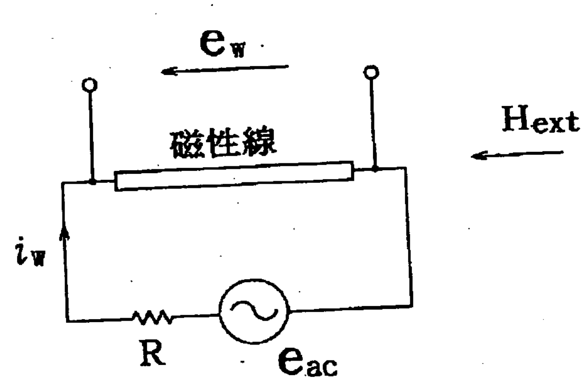
(54)【発明の名称】　磁気インピーダンス効果素子

(57)【要約】

【構成】時間的に変化する電流を磁性線に印加することによって生じる円周磁束の時間変化に対する電圧を、外部印加磁界によって変化させることを特徴とする磁気素子において、時間的に変化する電流として高周波を用いる。

【効果】通電電流を高周波化させることによって、ブリッジ回路を用いる必要がなくなり、数ガウスの磁界で50％以上のインピーダンス変化を得る非常に感度のよい小型の磁気インピーダンス効果素子が提供される。さらにこのインピーダンス効果素子を用いることによって、非常に感度がよく小型の磁気ヘッドが提供される。



【特許請求の範囲】

【請求項１】　時間的に変化する電流を磁性線に印加することによって生じる円周磁束の時間変化に対する電圧を、外部印加磁界によって変化させる磁気素子において、印加電流を時間的に変化する電流を高周波とする磁気インピーダンス効果素子。

【請求項２】　請求項１の磁性線が、アモルファス磁性線である磁気インピーダンス効果素子。

【請求項３】　請求項２のアモルファス磁性線が、円周方向に磁化容易方向をもつアモルファス磁性線である磁気インピーダンス効果素子。

【請求項４】　請求項２または３のアモルファス磁性線が、正磁歪をもつアモルファス磁性線としては長さ方向に圧縮力、負磁歪をもつアモルファス磁性線としては長さ方向に張力を印加して熱処理を施したアモルファス磁性線である磁気インピーダンス効果素子。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】この発明は、磁気インピーダンス効果素子に関するものである。さらに詳しくは、この発明は、オーディオテープレコーダ、ビデオテープレコーダ、コンピュータ、計測制御機器であるロータリエンコーダ、数値制御機器の磁気スケールなどに用いられている磁気ヘッドや各種の磁気センサ等として有用な磁気インピーダンス効果素子に関するものである。

【０００２】

【従来の技術とその課題】マイクロエレクトロニクス技術の発展にともなって、ＡＶ機器、コンピュータ、計測制御機器、数値制御機器等の小型高性能化が急速に進んでいる。特にコンピュータ関連機器に関してはそれが顕著であり、たとえば、コンピュータ用外部記憶媒体であるフロッピーディスクについてみると、直径が5インチのものから、さらに小型化が進み、今や２．８インチ時代を迎えようとしている。また、ハードディスクでは１インチ径のものに移行しようとしている。

【０００３】しかしながら、これらの各機器を小型化するには、その心臓部である磁気ヘッドを小型化する必要があるが、この磁気ヘッドの小型化は必ずしも容易ではなく、これを妨げる要因がある。ひとつの要因は、磁気ヘッド自体の大きさの問題である。つまり、従来の磁気ヘッドはコイルの巻線が必要であり、磁気ヘッド自体はどうしても大型化してしまう。もうひとつは、検出感度の問題である。つまり、小型化されると磁気ヘッドと記憶媒体の相対速度が低下して検出速度が小さくなり、したがって、検出感度が著しく低下してしまうということである。

【０００４】そこで、最近になって、従来の磁気ヘッドでは検出電圧が不足してくるため、磁束の時間変化でなく磁束そのものを検出する磁気抵抗素子をヘッドとして使用する動きが見られるようになってきた。これにより、小型化が一層押し進められてきた。ところが、現在の磁気抵抗素子は電気抵抗の変化率が最大６％以下と非常に小さく、また、数％の磁気抵抗変化を生じさせるのに必要な外部磁界は、２０ガウス以上と大きい。このため、磁気抵抗感度は、０．１％／Ｇ以下の低感度であり、このため信号対雑音比（Ｓ／Ｎ比）も非常に悪い。

【０００５】従って、磁気抵抗素子はブリッジ回路で抵抗変化のみを検出できるようにした上で着磁体に十分近接させて用いる必要があるが、実際には、たとえば、スピンドルモータなどのロータリエンコーダにおいては、ギャップマージンが数十ミクロン程度しかなく、細かいゴミの侵入によってもモータが停止するといった故障が生じ易い状態となっている。　このような磁気抵抗素子に対し、最近になって、巨大磁気抵抗効果とよばれる現象が磁性人工格子を用いる場合に見出されているが、この場合には、実際のところ、数十%の電気抵抗変化を得るのに数百ガウスもの大きな磁界が必要であり、さらに、ヒステリシスの問題もあり、小型化を指向する製品にはこの技術は適していない。

【０００６】そこで、このような従来の磁性抵抗素子や巨大抵抗効果を用いた素子の欠点を克服することのできる新しい素子をこの発明の発明者はすでに提案している。すなわち、まず、一般的に、磁性を持つ導線に交流電流などの時間的に変化する電流を流すと、導線の両端には二種類の電圧の和が現われる。それらは導線の電気抵抗と電流との積による電圧と、円周磁束の時間変化による電圧である。つまり、磁性線両端間の交流電圧ｅｗは一般に磁性線の電気抵抗Ｒによるオーミック電圧ｅＲ＝Ｒ・ｉw と磁性線円周方向磁束φθの時間変化ｄφθ／ｄｔによる誘電電圧ｅL ＝ｄφB ／ｄｔの２つの成分の和

ｅW ＝ｅＲ ＋ｅL

で表わせられる。通常後者の電圧は非常に小さいので、この電圧を利用することは、現在まで工学的にほとんどなかった。

【０００７】そこで、すでに発明者が提案した新しい素子は、時間的に変化する電流を磁性線に印加することによって生じる円周磁束の時間変化に対する電圧のみを、外部印加磁界による変化として検出することを基本的な原理としている磁気インダクタンス素子である。この磁気インダクタンス素子は、磁性線と、その磁性線の円周磁束の時間変化に対する電圧のみを取出す電気抵抗回路とからなる。図１はその磁気インダクタンス素子の例を示したものである。この図１の回路内の磁性線として、図２に示すように、FeCoSiB 等からなる零磁歪アモルファス細線等を折り曲げたものや直線状のものを用いることもできる。

【０００８】このような磁気インダクタンス素子内の回路により、磁性線に交流電流などの時間的に変化する電流（Iw）を印加し、電気抵抗分による電圧（オーミック

を印加した場合、｜ｅｗ｜は約５０％の減少を示している。このような現象はこれまでの磁性体ではみられなかった現象であり、とくにＭＲ効果が小さい（１％以下）アモルファス磁性線で現われたことはこれまでまったく予想されなかったことである。　図６は図５のｆ＝１ＭＨｚ，ｉｗ＝１５ｍＡにおける、ｉＷ，ｅw(Hext ＝０）およびｅw(Hext ＝10 (Oe)）の波形の写真である。この図６に例示したように、正弦波電流に対して、ｅW(Hext ＝０）の波形は角のある波形であり、ｅw(Hext ＝10 (Oe)）の波形はｉｗ の波形とほとんど同じである。このｅｗ （Hert ＝０）の波形は正弦波から著しくかけ離れた波形ではないのでｅｗ とｉｗ を正弦波と考えた場合、磁性線インピーダンスをＺとすると｜ｅｗ ｜のHext に対する変化は｜Ｚ｜の変化とみなすことができる。従って、この発明の磁気素子を磁気インピーダンス効果素子（Magneto-Impencance素子；ＭＩ素子）と呼ぶことにした。

実施例２

この発明の磁気インピーダンス効果素子について、アモルファス磁性線を高周波電流ｉｗ で通電励磁し、外部印加磁界の変化と｜ｅｗ ｜との関係である磁気インピーダンス特性を調べた。

【００２１】図７は実施例１で用いたアモルファス磁性線の磁気インピーダンス特性であり、ｆ＝１ＭＨｚにおいて、ｉｗ＝７．５ｍＡおよび１５ｍＡの場合を測定した結果である。この図７に例示したように、｜ｅｗ ｜はHext ＝５ (Oe) で約５０％減少しており、例えば図２に例示した交流電流を通電した磁性線に両端間の電圧を検出するだけのもっとも単純な回路を用いても、従来のフラックスゲートセンサに匹敵する非常に高感度の磁束検出素子を得ることが可能である。

実施例３

アモルファスの磁性線の径を変化させた場合のΔ｜ｅｗ｜／｜ｅｗ ｜の周波数特性を調べた。

【００２２】図８は実施例１で用いたアモルファスの磁性線を変化させた場合のΔ｜ｅｗ ｜／｜ｅｗ ｜の周波数特性である。この図８に例示したように、１２４μｍ径の磁性線および５０μｍ径の磁性線では、それぞれｆ＝２００ＫＨｚおよび６００ｋＨｚ近傍で変化率は最大を示した。特に、５０μｍ径の磁性線を用いた場合の変化率は、この３つの中で最も大きくその値は約６０％を示した。

【００２３】この磁気インピーダンス効果の起源は図５に示した２曲線から考察すると磁性線の内部インダクタンスＬｉ の変化と同時に磁性線の電気抵抗Rw が表皮効果により変化するためと考えられる。すなわち、表皮効果が強い場合（図５の実線ではｆ＞２００ＫＨＺ）にはインピーダンスＺは、δを表皮厚さ、ａを磁性線直径とすると、

【００２４】

【数１】

$$Z = R_w \frac{a}{2\delta} + j L_i \frac{2\delta}{a}$$

【００２５】となり、

【００２６】

【数２】

$$|Z| \propto \sqrt{\mu_0}$$

【００２７】（μ_0 ：円周透磁率）となるのでＨｅｘで μ_0 が減少し、｜Ｚ｜が大幅に減少する。

実施例４

この発明の磁気インピーダンス素子を磁界センサに用いた。図９はＭＩ素子・ＦＥＴ組合せによる共振型マルチバイブレータの例である。この共振型マルチバイブレータにおいては、３０μｍ径１㎜長の微細なアモルファス磁性線を用いて、２２０ＭＨｚの自己発振を生じさせることができ、±２ (Oe) までの外部印加磁界において、直線性の良好な磁界検出特性を得ることができた。共振は磁性線のインダクタンスとＦＥＴのソース・ドレイン間の内部キャパシタンスで生じている。この共振型マルチバイブレータにおいては、消費電力は非常に小さく８ｍＷであった。

【００２８】このＭＩ素子・ＦＥＴ組合せによる共振型マルチバイブレータの基本的な構造となるＭＩ素子の特性は、例えば、図１０に示した通りとなる。このＭＩ素子は２個のＭＩ素子に互いに逆のバイアス直流磁界Hb を印加して、各々のｅW の差が外部印加磁界Hexに正比例する。図１１は図７の自己発振回路のＭＩ素子にはＨｂ を印加せず、１個のＭＩ素子の先端のみをフロッピーディスク駆動スピンドルモータのロータリエンコーダ用３０㎜径５１２極着磁のリング磁石表面０．５㎜の位置に置いた場合の磁極磁界検出結果である。この場合磁極間隔は１５０μｍであった。磁気抵抗素子を用いた場合の数倍のギャップマージンで明瞭な磁極磁界が検出された。

【００２９】

【発明の効果】以上詳しく説明した通り、この発明によって、通電電流を高周波化させることによって、ブリッジ回路を用いる必要がなくなり、数ガウスの磁界で５０％以上のインピーダンス変化を得る非常に感度のよい小型の磁気インピーダンス効果素子が提供される。さらにこのインピーダンス効果素子を用いることによって、非常に感度がよく小型の磁気ヘッドが提供される。

【００３０】この発明の磁気インピーダンス効果素子を例えば磁界センサに用いた場合、従来のホール素子の感度を約１００倍向上させることが可能であり、さらに、ヘッドの使用温度は従来のホール素子の場合が７０℃程度で破壊されるのに対して、約２００℃まで増大することが可能となる。　またさらに、この発明の磁気インピーダンス効果素子をロータリエンコーダヘッドに用いる

と、従来のＭＲ素子に対して約１００倍以上の高感度を実現し、ヘッドと磁石表面のギャップを０．５mm程度に離すことができ、ごみの侵入による故障事故などをことが可能となる。この発明の磁気インピーダンス効果素子を用いれば非常に小型の地磁気利用電子方位素子やマイクロマシン用のマイクロ磁気センサ、高感度の磁気探傷センサアレイ、生体磁気センサなど各種の高感度マイクロ磁気センサが可能となる。

【図面の簡単な説明】

【図１】従来の磁気インダクタンス素子を示した概略図である。

【図２】従来の磁気インダクタンス素子の磁性線を示した平面図である。

【図３】（ａ）（ｂ）（ｃ）（ｄ）は、各々、従来の磁気インダクタンス素子を用いた磁気インダクタンスの波形を示した波形図である。

【図４】この発明の磁気インピーダンス素子を示した概略図である。

【図５】磁性線両端間の電圧と高周波電流の周波数との関係を示した相関図である。

【図６】この発明における出力波形を示す波形図である。

【図７】磁性線両端間の電圧と外部印加磁界との関係を示した相関図である。

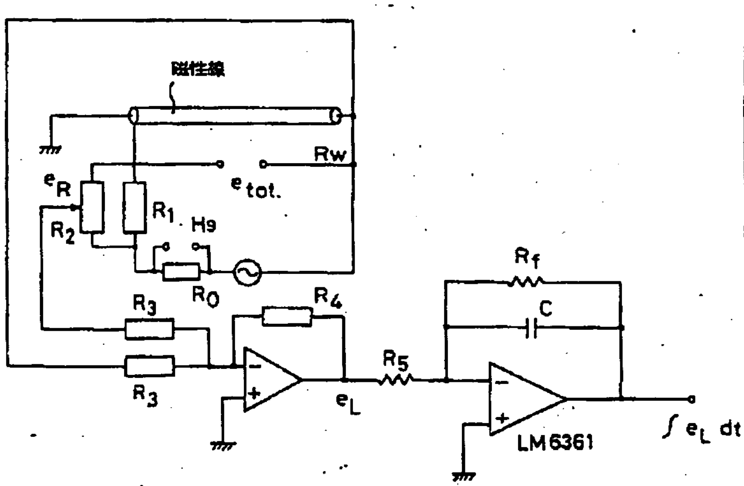
【図８】磁性線両端間の電圧の変化率と高周波電流周波数との関係を示した相関図である。

【図９】この発明の磁気インピーダンス素子を磁界センサに用いた場合の概略図である。

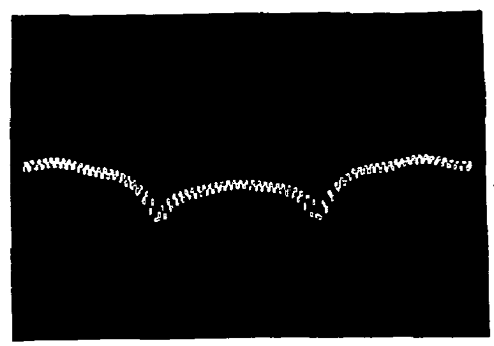
【図１０】この発明の磁気インピーダンス素子を磁界センサに用いた場合の磁性線両端間の電圧と外部印加磁界との関係を示した相関図である。

【図１１】磁極磁界検出結果を示した波形図である。

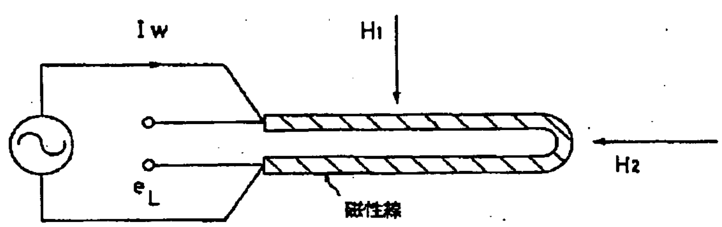
【図１】



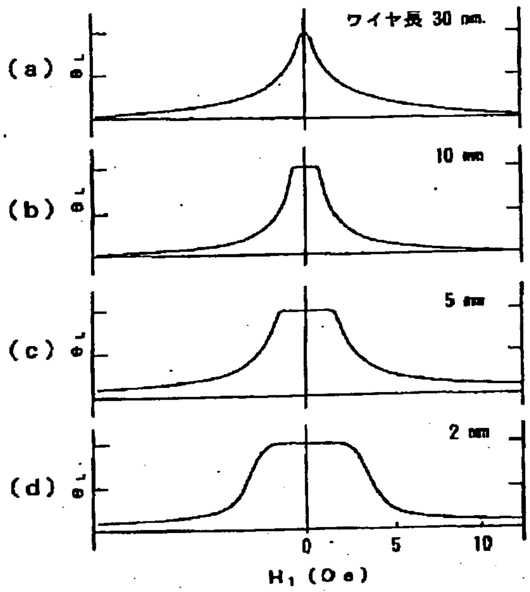
【図１１】



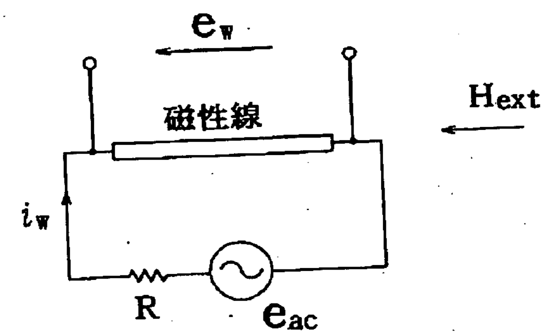
【図２】



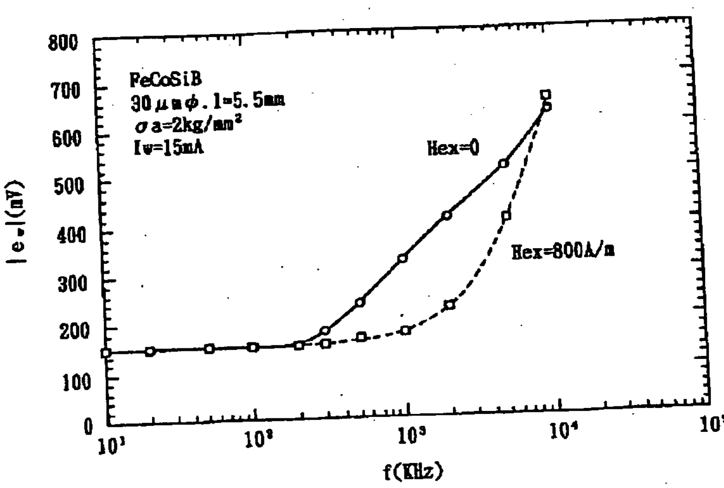
【図3】


ワイヤ長 30 mm.
10 mm
5 mm
2 mm
(a)
(b)
(c)
(d)
0
5
10
H₁ (Oe)

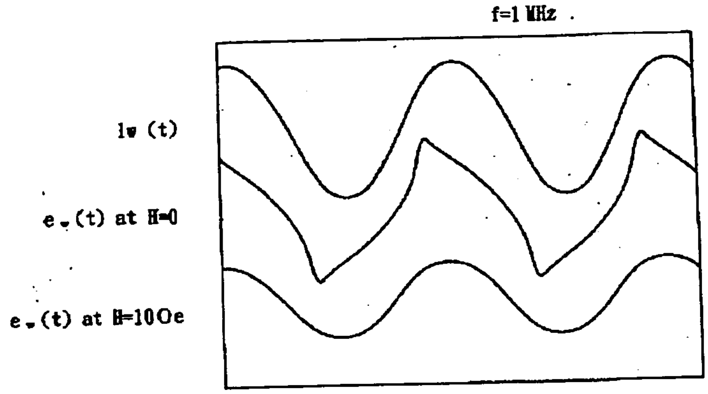
【図4】


e_W
磁性線
Hext
i_W
R
e_{ac}

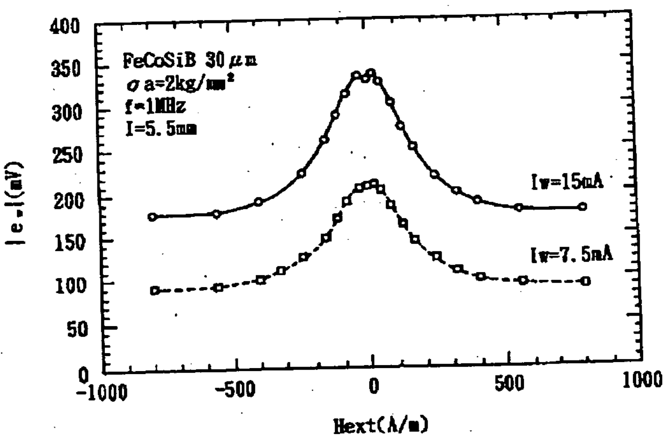
【図5】


FeCoSiB
30μmφ.l=5.5mm
σa=2kg/mm²
Iw=15mA
Hex=0
Hex=800A/m
|eW|(mV)
f(KHz)
800
700
600
500
400
300
200
100
0

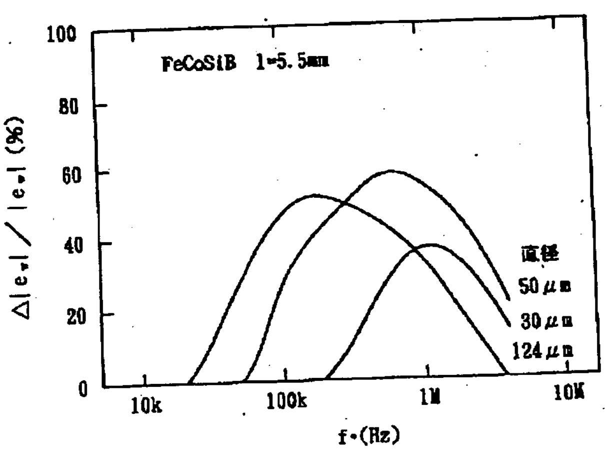
【図6】


f=1 MHz
Iw (t)
e w (t) at H=0
e w (t) at H=10Oe

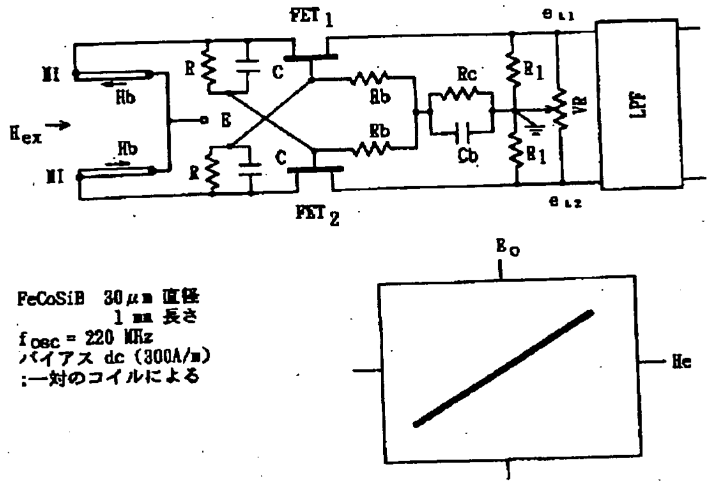
【図7】


400
350
300
250
200
150
100
50
0
FeCoSiB 30μm
σa=2kg/mm²
f=1MHz
I=5.5mm
|e w|(mV)
Iw=15mA
Iw=7.5mA
-1000
-500
0
500
1000
Hext(A/m)

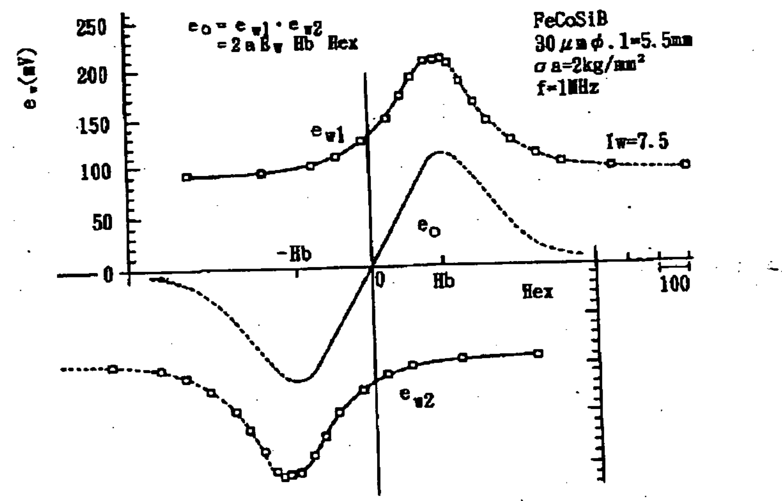
【図8】


100
80
60
40
20
0
FeCoSiB l=5.5mm
Δ|e w| / |e w| (%)
直径
50μm
30μm
124μm
10k
100k
1M
10M
f·(Hz)

【図9】



【図10】



フロントページの続き

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